The study on the cognitive spatial structure based on the user's experience

The visual factors on the car navigation map as a basis

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Abstract: The main purpose of the spatial display of car navigation is to provide the feeling of one's location, movement and direction to the user. At this time, the 3-dimensional spatial concept is projected into the 2-dimensional interface area. The user comprehends and thinks the distance, the present and the future through the reconstructed 2-dimensional interface. As a result, to represent the space in the flat interface appropriately, the study for the cognitive spatial structure based on the user's experience is needed.

This study took four steps to conclude the efficient spatial structure with which the user can rapidly recognizes object in the map interface of the car navigation. Firstly, we summarized the theories on the cognitive limits when one executes multiple tasks, the user's experience on the place and the eye movement between visual factors. Secondly, we analyzed the spatial structure of the widely-used navigation based on the theory and made diagnosis of the problems. Thirdly, we executed an expert evaluation based on the theory and the analysis of the present state of the navigation. Fourthly, we concluded the layout of spatial structure of the car navigation through the expert evaluation.
As the visual distraction during the driving has a direct connection with the driver's life, more detailed care and the concentration are needed in designing the car navigation map.

The study considering the information characteristics of the map interface of the car navigation would prevent the visual distraction that could be occurred during the driving and help the user to drive safely.

Key words: Car Navigation, Map Display, Information Characteristic, 3-dimensional spatial

1. Introduction

A car helps us to move conveniently, at the same time, it threatens our safety and life. A car is moving fast and there are plenty of dangerous factors out there. Furthermore, if the road is the one that a driver has never traveled before, the danger factors increase.

When one drives, one executes two tasks which are driving and finding a route. McGranaghan, Mark and Gould(1987) defined that the process the drivers use when following a given route is as follows. The driver views the presented information from the current display and takes the appropriate actions. If the 'view-action' pair is completed, the next turning point information is presented and the driver shows the appropriate reaction to that situation. This whole cycle is repeated. At this time, if the driver spends too much time recognizing navigation information, the driver's safety is threatened due to the distraction of visual concentration. So it is crucial to reduce the amount of time interpreting navigational information.

The market for navigation has been growing quickly from the beginning of the 21th century. The description level of navigational graphic images has been improving due to the growth of memory capacity and technology developments. But, there are no standards for the consistent spatial structuring of visual factors of a navigation map. This implies, in making navigation maps that, there are no spatial structure standards that include the user's need to recognize features quickly.

The main purpose of the spatial display of the car navigation is provide a user with a grasp of one's location, movement and direction. At this time, the 3-dimensional spatial concept is projected into the 2-dimensional interface area.

The user comprehends and thinks the distance, the present and the future through the reconstructed 2-dimensional interface. As a result, to represent the space to the flat interface appropriately, the study for the arrangement of relative location and the allocation of the visual factors considering the user's cognitive aspect in the 2-dimensional interface according to the information characteristics is needed.

In this paper, we examine the reconstruction of the visual factors of a map while considering the user's cognitive abilities with the hope of determining approaches that my improve the user's recognition time and thus act, improve as assistance for the safe driving.

2. The Background Theory

2.1. The Limitations in the Cognition of a User

The typical visual monitoring behavior of a driver includes careful watching which alternates between the road and a display, and this is commonly called switching[1]. According to Lee,Jae-shik(2000), the switching occurs every 1.0~1.5 seconds; thus, it requires relatively a lot of attention in order to understand information even with a well-designed display system.

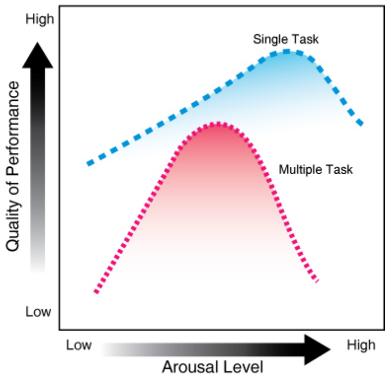

Figure.1 Performance operating characteristic (POC)

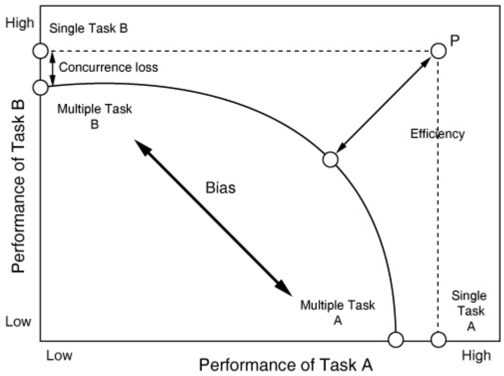

Figure.2 The Yerkes-Dodson law

Drivers drive while performing multiple jobs, at the same time. According to Park, Chang-ho(2006), drivers perform two tracking tasks when controlling a vehicle. First, there is a 'horizontal' control task in order to maintain a lane, and, second, there is a 'longitudinal' control task that detects the behavior of a vehicle, risk factors, and traffic signals. Drivers are offered visual information at different dimensions throughout these two tasks. At that time, when there appears to be a division of attention, target acquisition becomes somehow low compared to when target acquisition is proposed within a single resource[2]. Figure 1 shows a performance operating characteristic (POC) curve that measured efficiency during the performance of dual tasks. It is found that when carrying out the dual tasks of A and B, the efficiency considerably falls short of the sum (P value) during the independent performance of the two tasks. Also, the performance of dual tasks demonstrates a lower efficiency when compared to the performance of an independent task even if the relative importance of the performance may be placed too heavily on any one task. Such a loss may be connected to the trouble related to arousal concerning a problem. The Yerkes-Dodson law in Figure 2 exhibits the level of arousal that occurs during the performance of a single task and a combined task[2]. According to the Yerkes-Dodson law, the level of arousal drops when performing a combined task compared to when performing a single task. The low level of arousal may incur an error during the performance of a task set, and impair concentration on a close watching task.

2.2 Understanding of Users' Perception Process

Humans live through cognitive activities perceiving, paying attention, memorizing, and learning an object in daily life as well as using language, thinking and feeling. Those activities are the higher mental activity that obtains knowledge and information, changes, and produces them through various individuals inside and outside stimulations in various life scenes[8]. As such, the mental activity is hard to explain only through the cognitive process. For that reason contextual experiences around systems and users, and understanding of situations are required. Such a series of cognitive activities can be examined through the 'mental model', information that users can employ to characterize the environment by using systems such as 'situation perception' through which users can properly understand actual situations and conditions.

2.2.1 Mental model through experiences

When a human recognizes the space, the space and the time is given. The time in this context indicates 'the present' time. In recollecting the route, the past experience interacts with the present recognition when one recognizes the space. In other words, the memory formulated from the past experience of the space influences the memorization process of the present space and the present experience of the space also influences the memory of the past space experience. As a result this interactive process modifies the past memory.

People have a tendency to react quickly to the expected object, but they do not react quickly to the un-expected object. This expectation role is important to the driver's recognition [7], as a result the design should be made to use the properties of the expectation effect[2].

In other words, it is very crucial to understand the mental model which explains underlying relationship between the user's experiences and space perception in developing and designing navigation. What mental model users have is the key to the development for not only navigation but also many developing systems.

For example, it is hard to figure out how to deal with a complex menu and an operation board at a glance, so if a relevant indicator or a mental model connecting operation buttons is provided, it is effective. Roscoe(1968), Roscoe, Corl, and Jensen(1981) suggested 'a principal of the moving part'. The direction of movement of an indicator showing variables on the display should be consistent with the moving direction of the mental model of an operator [4]. For example, the thermometer for family use rises according to the fever, which is consistent with the principal and the direction of movement. The principal and the direction of movement is inconsistent sometimes in the actual use[4]. For another case, when one holds a complex TV remote control in a hand, a user can make possible connection of context called symmetry(channel is lateral transfer: equal relationship, the volume is up & down transfer : size difference) about two operation buttons. Therefore, uses can perceive easily without special training. The exact mental model about the system contributes to deciding how to operate the system and gives information how to deal with system failure or errors[2]. Moreover, as cognitive errors in equipment such as the medical equipment and the flight operation device cause big accidents, so the design using the mental model is very useful as users can operate efficiently.

2.2.2 Situation awareness

While a driver is in a traffic jam, they want to know when the road will be cleared, where they are now and how long they will drive more. Knowing the answers makes the driver relieved from the stress and helps safe driving. Like this, knowing our current situation and how the situation will be changed is called situation awareness.

Situation awareness provides a frame of interpretation about the currently happening situation, so it brings about general contextual effects. Also, the errors of situation awareness can be a decisive factor leading to a wrong decision and a wrong performance[2]. Therefore, correct navigation interfaces need to point out various environmental attributes necessary for situation awareness as well as to consider possible situations(alternatives). Moreover, information about the current road and the remaining road of a journey makes the driver not bored and helps safe driving.

Situation awareness can be thought as a mental model of a situation[2]. We recognize the object being distant when it is located relatively on the top of the horizontal line of the display[6]. Also, the warm color looks close, the cold color looks distant and the color possessing the high saturation value looks close to the observer in contrast to the color possessing the low saturation value [6].

As a result, in using the navigation, if the arrangement of the visual factors is standardized, the drivers can easily expect where to look at to get the information or to take an appropriate traffic action at some event[2, 7].

3. The analysis of spatial structure of navigational map interface

The visual factor expands our experience on the space and the shape. Furthermore, it helps us to recognize extended outer environmental information. This chapter discusses the visual factors comprising the space of the car navigation map (4 types) and examines the visual factors that are arranged without considering the cognitive aspects.

3.1. The analysis target and the method

80% of the current domestic (South Korea) car navigation market is occupied by ThinkWare and M&Soft. So, to make this study representative, the two representative models of the two software companies are selected for analysis model (ThinkWare K2, G1 and M&Soft JINI, Mappy). Figure 3 shows the map interface of the selected four domestic navigational devices. Starting from the upper left, each figure indicates Mappy (M&Soft), G1 (ThinkWare), K2 (ThinkWare), JINI (M&Soft) in clockwise direction.

Figure.3 The map interface of the selected four domestic navigational devices

The visual factors appearing in the spatial structure are classified by 9 categories. The criteria for the classification are visual factors for the position and the direction of movement; each factor is shown on the four analysis examples. The visual factors of the navigation map consists of 1) current position, 2) the upcoming route, 3) the change of road direction, 4) background, 5) road(street, pedestrian passage), 6) the traffic lane information, 7) the environment symbol, 8) text, 9) controllable menu.

Figure.4 Visual factors

3.2. The analysis result

Our spatial structure analysis of the visual factors shown on the four devices, indicates that are no standards for showing the traffic lane information, the change of road direction, or the controllable menu except the current position of the driver and basic factors. Also, the size and the contour lines of the visual factors are not shown consistently.

4. The study of the visual factors of the car navigation map through expert evaluation

4.1. The subject and the method for the evaluation

A. For the evaluation, the GUI experts are asked to reply to open-ended questions without knowing other's opinion. They were offered a device manual and an enough time to proficiently control the devices.
B. Categorize the non-systematic reply on the open-ended question which is just taken once (common opinion, opposite opinion and the other opinion) and redistribute it to the panels. At this time, one can reference the other's opinion which is obtained by redistribution and use that information to reinforce or retract one's opinion.
C. Collect the replies from the panel that are taken twice and summarize the consensus opinion. The participants for the evaluation consist of four GUI expert and the subjects for the evaluation are restricted to the four types of navigation(iNavi G1, K2, JINI, Mappy).

4.2. The evaluation result

The open question given on the 1st evaluation phase was 'analyze the spatial structure of the car navigation and propose the problems and improvements'. Four GUI experts freely replied.

The evaluation criterion was based on 'spirit model' of the experience in the user's point of view and recognition. The 1st evaluation was taken by the one expert and one tester (1:1) and was occurred within approximately 1~2 hours. The contact between experts was prohibited during the evaluation. The first answers for the evaluation were summarized considering redundant and opposite opinions. And the results were put together into one answer sheet. When looking into the first answers for the evaluation, the opinions about the relative location of the visual factors, the route and the center of the eyes were dominant. The following are opinions. 'is it adequate to locate the visual factors of the route using the user's current location as a basis', 'was the route(moving path) used appropriately to grasp the user's moving direction', 'is the main route located on the point where the user's center of the eyes resides', 'doesn't the background distract the user's sight (the route navigation, the symbol). The summarized first opinions were redistributed to the four experts using e-mail excluding the opinions not relating to the spatial structure. At this time, the evaluators were given the chance to modify or retract one's previous opinion and were given the chance to agree or disagree to the proposed problems and improvements made by others.

The collected opinions were filtered to only pick out the opinions on which more than 3 evaluators agreed on. The results are as follows. 'A consideration for the user's spatial comprehension is needed', 'A representation of the visual hierarchy according to the priority of the information of the image is needed', 'A categorization of groups by grouping the relevant information is needed', 'The need for the location classification based on the importance of information and the frequency of its use', 'Too many visual factors should not be concentrated on one spot'.

Table 1. The evaluation result

• A consideration for the user's spatial comprehension is needed**.**
• A representation of the visual hierarchy according to the priority of the information of the image is needed.
• A categorization of groups by grouping the relevant information is needed.
• The need for the location classification based on the importance of information and the frequency of its use.
• Too many visual factors should not be concentrated on one spot.

Wickens said that the user has a 'spirit model' according to a familiarity. If the user has familiar location, direction and shape, then the user can recognize rapidly and easily. For examples, when representing top and bottom and right and left in organizing the display map, the user can recognize the upward sign more rapidly when it is located on the top than when it is located on the bottom. Similarly, the user can recognize the downward sign more rapidly when it is located on the bottom than when it is located on the top. When representing the feeling of the distance, the user recognizes the object being distant when it is located relatively on the top of the horizontal line of the display and recognizes the object being close when it is located on the bottom. As a result, one should distribute the time-space information to the vertical region of the display (the present, the future, far and near) with consideration of the user's spatial comprehension.

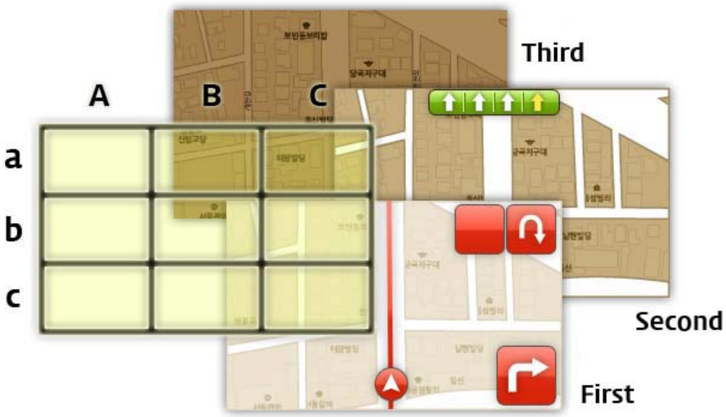

Figure 5 The 3 Dimensional spatial division of the map

Also, the user recognizes and understands the space sequentially according to the power being pulled. As a consequence, there should be a location classification based on the cognitional experience on the space and the frequency of use. At this time, it is needed to maintain the visual balance through evenly distributing the visual factors on the display and to minimize the eyes movement by locating the similar visual factors close together.

Also, the visual factors can be divided into the important and the unimportant factors according to the characteristics of the information. The important information should be laid on the driver's visual center and the immediate recognition should be accomplished. Therefore, by grouping the visual factors according to the importance and the characteristics of the information, the representation of the visual hierarchy between these groups should be realized. The hierarchy of the groups makes the important visual factors remarkable that it induces the driver's immediate recognition.

4.3. The design of the layout

The space is divided into 3 parts by the horizontal, the vertical and the depth according to the result obtained by expert evaluation.

Table 2. The proposal for the right spatial structure of the car navigation

The horizontal division_ the degree of the importance, the frequency, the need for the user control A. the controllable menu, unimportant information B. The information about the self, important information C. The auxiliary information for grasping my moving direction
The vertical division_ the present and the future, the far and the near, cognitional experience a. The information representing the upcoming route b. The information not being affected by the time and the space c. The information about the current location
The division by depth_ the grouping of the visual factors by priority of the information, enhancing rapid eye movement First phase : my current location, the upcoming route, the change of direction Second phase : the route (the lane road, the pedestrian passage), the traffic lane information Third phase : a background, a text, an environmental symbol

By analyzing the evaluation result, we could see that the importance of the information, the frequency and the need for the user control became the criteria of the information types on the horizontal structure. When examining the horizontal arrangement, the left side of the display was occupied by the unimportant information needing the user control while taking into consideration the difficulties of receiving the direct visual concentration of the user. The center of the display where the center gaze resides was occupied by the important information including the self information and the right side of the display was occupied by the auxiliary information for grasping the direction of movement.

By analyzing the evaluation result, we could also see that the time space information like the present, the future, the near and the far became the criteria of the vertical structure. Based on the center of the display, the top region was occupied by the information representing the upcoming route, the center region was occupied by the information not being affected by the time, and the space and the bottom region was occupied by the information about the current user's location. After finishing the arrangement of the space, we could see that the display division was largely influenced by the user's gaze and the gaze moved from the center, right and left order. Also, we could see that the user recognized the 3 dimensional time space concept (the far and the near, the present and the future) as the top and bottom of the 2 dimensional interface.

The depth structure is grouped by the importance of the visual factors and thus the visual hierarchy is classified as 3 phases according to the group level. There are 3 phases in classification. The first phase is based on the intuitive information (my current location, the upcoming route and the change of direction). The second phase is based on the symbols, texts and the moving route that are required to grasp a school, a hospital and environment (the land road, the pedestrian passage, the traffic lane information). Lastly, the third phase is based on the background information (the background, the text, the environmental symbol).

At this point, the visual factors that have a top priority need to be visually emphasized in contrast to the other factors. On the other hand, the factors that have a low priority need to reduce the visual significance by minimizing the color contrast and lowering the saturation in order not to distract the visual attention of the driver. This is to make the eye movement easier between the top prioritized visual factors when the jump exercise arises.

5. Conclusions

The people have a tendency that they react fast to the expected object, but they do not to the un-expected object. This expectation role is important to the driver's recognition [7] and, as a result, the design should be made utilizing the properties of the expectation effect[2]. In using the navigation, if the arrangement of the visual factors is standardized, the drivers can easily understand where to look at to get the information or to take an appropriate traffic action at some event [2,7].

This study took four steps to conclude the adequate spatial structure with which the user can rapidly recognizes objects in the map interface of the car navigation. Firstly, we summarized the mental model of the user's experience and the theory about the visual points. Secondly, we analyzed the spatial structure of the widely-used navigation based on the theory and made a diagnosis of the problems. Thirdly, we executed an expert evaluation with the theory and the analysis of the present state of the navigation. Fourthly, we concluded the layout of spatial structure of the car navigation through the expert evaluation. The proposed spatial structure is divided into 3 parts by the horizontal, the vertical and the depth.

As the visual distraction during the driving has a direct connection with the driver's life, more detailed care and the concentration are needed in designing the car navigation map. This study expects that considering the information characteristic of the map interface of the car navigation would prevent the visual distraction that could be occurred during the driving and help the user to drive safely.

6. References

[1] Lee,Jae-shik. (2000) Analysis of Driver`s Front - To - Rear - End Collision Avoidance Behavior Using a Driving Simulation Study vol.13 No.2(pp53-73). The Korean Journal of Industrial and Organizational Psychology.

[2] Park, Changho collaborate on 9. (2007) Cognitive engineering psychology. Sigmapress.

[3] Edward Relph. Kim, deokheon collaborate on 2 (2008) Place and Placelessness. Non-heon.

[4] Christopher D. Wickens, kack howan translation. (2003). Engineering psychology and human performance. Sigmapress.

[5] Kim jeongeun. (2008) The study on map display of car navigation for improvement of user recognition. hongik University. Seoul. S.Korea.

[6] Zettl. Kim dongho translation. (1998). Applied media aesthetics. Samkeong.

[7] Theeuwes, J. & Hagenzieker, M. P. (1993). Visual search of traffic scenes: On the effect of location expectations. In A. G. Gale et al.(eds.), Vision in Vehicles IV(pp.149-158). Amsterdam: Elsevier Science Publishers B. V.

[8]Lee, Jeongmo collaborate on 9 (1998). Cognitive psychology. Hakjisa.